CICOTT STREET BRIDGE
Spanning the Wabash River at State Road 25
Logansport
Cass County
Indiana

HAER No. IN-69

HAER
IND
9-LOGPO,
2-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
U.S. Custom House
200 Chestnut Street
Philadelphia, PA 19106

HAER
IND
9-LOGPO,
2-

HISTORIC AMERICAN ENGINEERING RECORD

CICOTT STREET BRIDGE

HAER No. IN-69

Location:	This bridge spans the Wabash River on SR 25 (Cicott Street) about 0.3 mile south of US 24 in Logansport, Cass County, Indiana UTM: 16.552580.4510680 Quad: Clymers, Indiana
Date of Construction:	1913. Altered 1957 and 1969.
Present Owner:	Indiana Department of Transportation Indiana Government Center North 100 North Senate Avenue Indianapolis, Indiana 46204
Present Use:	Vehicular bridge.
Significance:	This bridge is judged to be locally significant and to be eligible for inclusion on the National Register of Historic Places. It was designed and constructed by Daniel B. Luten, a nationally known engineer and bridge designer who lived in Indianapolis, and the bridge is considered to be a strong example of Luten's skill as a designer of concrete arch bridges.
Project Information:	This documentation was undertaken in 1991 in accordance with the Memorandum of Agreement by the Indiana Department of Transportation as a mitigative measure prior to the destruction of the bridge.

Curtis H. Tomak
Environmental Specialist
Environmental Assessment Section
Division of Program Development
Indiana Department of Transportation
Indianapolis, Indiana

Table of Contents

	Page
The Cicott Street Bridge Replacement Project	3
Significance of the Cicott Street Bridge	3
Daniel B. Luten: Bridge Designer and Builder	3
The Luten Arch	4
The 1913 Flood and the Construction of the Cicott Street Bridge	5
The Cicott Street Bridge	6
Sources of Information	8
Figure 1 (location of the Cicott Street bridge)	11
Figure 2 (location of the Cicott Street bridge)	12
Supplements (pages from a National Bridge Company booklet)	13

The Cicott Street Bridge Replacement Project

Indiana Department of Transportation (INDOT) Project ST-H104( ), 25-09-7409(4179A), involves the replacement of the concrete arch bridge over the Wabash River on Cicott Street (SR 25) in Logansport, Cass County, north-central Indiana. Logansport is situated at the confluence of the Wabash and Eel rivers in the upper portion of the Wabash Valley. The Wabash flows southwest into the Ohio River at the southwestern corner of Indiana. Cicott Street runs north and south in the southwestern part of the city, and the bridge is approximately 1600 feet downstream from the confluence of the Wabash and Eel rivers. Refer to Figures 1 and 2 and Photograph 9.

The Cicott Street bridge needs to be replaced due to its deteriorating condition and the narrowness of the structure. It is situated in a built-up urban area, and it has been determined that there is no feasible and prudent alternative to replacing the bridge on existing alignment (Juricic 1990; Ralston 1990). Thus, the bridge will be destroyed as a result of the construction of the project.

Significance of the Cicott Street Bridge

The Cicott Street bridge has been determined to be of local historical significance as an important river crossing in the city of Logansport (Ralston 1990) and to be eligible for the National Register of Historic Places (Ridenour 1987). Its significance depends to a considerable extent upon the fact that it was designed and constructed by Daniel B. Luten, a nationally known engineer and bridge designer who lived in Indianapolis, and that it is "a strong example of Luten's skill as a designer of concrete arch bridges" (Ridenour 1987).

Daniel Benjamin Luten: Bridge Designer and Builder

Daniel Benjamin Luten was a nationally known expert in the design and construction of reinforced concrete arch bridges. He was born on December 26, 1869, in Grand Rapids, Michigan. In 1900 he married Edith Head Hull of Lafayette, Indiana, with whom he had four children. Mr. Luten died in Indianapolis at age 76 on July 3, 1946. Refer to: Anonymous 1930, 1946, 1950; Luten n.d.

Mr. Luten received a B.S. degree in Civil Engineering from the University of Michigan in 1894 and taught civil engineering there in 1894 and 1895. He resigned to take a position as Instructor in Civil Engineering at Purdue University, West Lafayette, Indiana, in 1895 and taught arch design, stereotomy, and hydraulic theory at Purdue from 1895 to 1900. In 1900 he resigned from the facility of Purdue to practice civil engineering and soon began specializing in reinforced concrete arch bridges for which he became famous. As of 1930

Luten had supervised the design and construction of about 15,000 concrete bridges end had been grented some 50 U.S. patents for improvements in bridge construction including the Luten concrete arch. He also contributed articles based on his bridge research to technical journals and was a member of numerous professional organizations. In eddition, he served on the Indiana State Board of Professional Engineers and was a founding member of the Scientech Club at Purdue. Refer to: Anonymous 1930, 1946, 1950; Luten n.d.

Daniel Luten moved to Indianapolis in 1901, living there the rest of his life (Anonymous 1946). It was in Indianapolis that he formed the National Bridge Company in 1903 (O'Connor 1979). He was president of the company and was its driving and controlling force. The National Bridge Company worked nationwide and in foreign countries, specializing in concrete arch bridges, and had several subsidiaries (including Luten's National Concrete Company) as indicated on the title page of a National Bridge Company booklet (Anonymous 1907; attached as e supplement).

In 1918 the National Bridge Company incorporated under the name of the Luten Engineering Company, changing its focus from complete construction of bridges to designing, consulting, end supervising the construction (O'Connor 1979).

Within a short time of Luten's death in 1946, the company ceased its operations, terminating its existence in 1947. During its existence the company and its subsidiaries designed and were involved in the construction of all of the Luten arches in the world (O'Connor 1979).

The Luten Arch

During his stay at Purdue (1895 - 1900) Daniel Luten began developing the ideas for the concrete arch bridge which was to come to be known as the Luten erch. Luten arch bridges have an arch or a linear sequence of arches made of concrete reinforced with steel rods. The side walls (spandrel walls) of these bridges rise above the arches to form a partially enclosed, trough-like, area which is filled with earth. The roadway is constructed upon the earth fill.

The Luten arch was advertised as being 50 percent stronger than any other comparable bridge, and advantages of Luten built bridges were listed in publications put out by Luten for advertising purposes as indicated on pages 92 and 93 of a National Bridge Company booklet (Anonymous 1907; attached as a supplement). Some of those publications also discussed the steps and considerations involved in Luten arch bridge construction as exemplified by pages 82 to 91 of the 1907 booklet (ettached as a supplement). That document and other publications (e.g. Luten n.d.), publicized Luten's work by picturing several to numerous examples of his bridges during and after construction.

The 1913 Flood and the Construction of the Cicott Street Bridge

Severe weether ceused disastrous flooding in the Midwest in March 1913 which washed out the bridges spanning the Wabash River at Logansport. One of those bridges was the structure et Cicott Street. Accounts of the flood and information relating to the construction of new bridges, one of which is the presently existing Cicott Street bridge, occur in Logansport newspapers, copies of which are in the newspaper archives of the Indiana State Library in Indianapolis. Those newspepers are the Logansport Journal-Tribune (LJT) and the Logansport Pharos (LP), the latter subsequently becoming the Logansport Pharos-Reporter (LPR).

The main headline of the Logansport Journal-Tribune for March 26, 1913, reads: "GREATEST FLOOD IMPERILS THIS CITY, HIGH WATERS IMPRISON HUNDREDS IN THEIR HOMES, THE WABASH IS A SEA; FLOOD SUFFERERS ARE GIVEN PROMPT RELIEF; NO LIVES LOST YET." The first sentence of the story is as follows: "The greatest flood in the history of the city swept Logansport yesterdey, bringing destruction to property end desolation in its wake." An accompanying headline refers to the plight of the city of Peru which is about 15 miles upriver from Logansport. It reads: "200 DEAD IN PERU - City Is a Waste; 10,000 Homeless and in Need of Food; Aid Is Coming."

It was imperative that the bridges be rebuilt as soon as possible, and the City and County took immediate action to get that done. By April 1913 $45,000 had been appropriated for the Cicott Street bridge (LP, p.2, April 16, 1913). In a newspaper eccount for June 3, 1913, the bids for the bridge are reported to range from $39,260 to $44,900 for e concrete structure and from $42,654 to $45,000 for e steel bridge (LPR, p. 2). Newspapers for June 4 report the awerding of the contract and provide some information about the new bridge at Cicott Street (LJT, p.1; LPR, p.3). The Cass County Commissioners awarded the contract for the bridge to the National Concrete Company in Indianapolis at a cost of $44,750. The Netional Concrete Company was run by Daniel B. Luten who was its president. The Cicott Street bridge was to be completed by December 1, 1913. It was to be 645 feet long and to have a roadway width of 35 feet.

In regard to awarding the contract for the Cicott Street bridge and contrects for other bridges in Logensport end Cess County to Luten, County Commissioner Lienemann stated the following:

> "Our main obligation was to buy the best bridge we could get, that's what the public looked to us to do. We could not afford to take chances so we investigated thoroughly and decided we would construct bridges like the one put up at Georgetown. What

> the people wented us to do above all things was to put in bridges that would not wash away and would not make possible a recurrence of the flood this spring" (LJT, p.1, June 4, 1913).

The Cicott Street bridge was built by Luten's company in 1913, and, although some repair work was necessary in 1957 and in 1969, it has served Logansport for these past 79 years.

The Cicott Street Bridge

The Cicott Street bridge is e concrete arch structure that was constructed by Cass County in 1913. The precise date at which the bridge became part of the State highway system is not known. The earliest State written records that we can find for the bridge are the 1957 "Stete Highway Department of Indiana" repair plans which show that the bridge had been taken over by the State by 1957. However, based upon old highway maps, it appears that SR 25 was routed over the Cicott Street bridge about 1933, indicating that the bridge was incorporeted into the Stete system et that time (Bartlett 1992).

The earliest picture that we have of the bridge is a postcard postmarked 1949 (Photograph 8) which was found among the Cass County photographs at the Indiana State Library in Indianapolis. That card presents an overall view of the bridge end shows spans (arches), piers, sidewalls, and railing.

The earliest plans that we can find for the Cicott Street bridge are the 1957 "State Highway Department of Indiana" repair plans for the bridge. They are included in a set of repair plens for six bridges at Logansport, and only sheets 1, 5, 6, and 12 of that set (Photographs 9-12) pertain to the Cicott Street bridge.

The 1957 plans present a cross section and e plan view of the bridge. From south to north the lengths of the six spans are given as 98 feet 4 inches, 103 feet 4 inches, 109 feet 8 inches, 109 feet 10 inches, 103 feet 5 inches, and 98 feet 6 inches. The maximum total length of the bridge (tip of endwall to tip of endwell) is shown to be ebout 660 feet. The roadway width is 26 feet, and there are 4.5 foot sidewelks along each side of the roadway. Sheet 5 of the 1957 plans (Photograph 10) shows the original character of posts in the railing of the bridge and the replacement reiling which was installed in or about 1957. The original concrete posts were decorative and consisted of two rounded sections placed one on top of the other with a constriction or waist where they joined. The new concrete reiling consists of a caprail set on e supporting section composed of a series of rectangular posts separated by rectanguloid portals. According to the 1957 plans, other work done to the structure included patching damaged ereas of concrete and replacing pavement, curbs, and sidewalks.

One other set of plans is known for the Cicott Street bridge. It consists of four sheets of repair plans dated 1969 (Photographs 13-16) which were prepered by the Indiena Stete Highway Commission. Sheet 2 of the 1969 plans (Photograph 14) furnishes a cross sectional drawing, plan view, and lateral view of the bridge and provides a good illustretion of the basic character of the original bridge. The plans show the bridge to be a six span reinforced concrete arch structure set on concrete piers and abutments. From south to north the span lengths are given as 98 feet, 101 feet, 107 feet, 107 feet, 101 feet, end 98 feet. The maximum total length of the bridge (tip of endwall to tip of end-wall) is shown to be about 660 feet. The sidewalls (spandrel walls) of the bridge rise above the arches to form a trough-like erea which is filled with earth. The paved roadway rests upon the eerth fill. The roadway consists of two 13 foot driving lenes, each of which is paralleled by a sidewalk which is 4.5 feet wide.

The 1969 repairs included the replacement of pavement, curbs, and sidewalks end the instellation of tie rod assemblies to stabilize the sidewalls (spendrel walls) of the bridge. Each assembly basically consists of two steel I-beams end tie rods to connect them. An I-beam is placed on the outside of a sidewall of the bridge, and another is placed opposite it on the outside of the other sidewall. Steel tie rods ere bolted to one I-beam, pass through the earth fill under the roadway, and are bolted to the opposite beam. These assemblies hold the sidewalls of the bridge in place. The tie rod assemblies are shown and detailed on sheets 3 end 4 of the 1969 plans (Photogrephs 15 and 16) and are visible in photographs of the bridge taken in 1990 (Photogrephs 1-7).

The present Cicott Street bridge is illustrated by photographs taken in November 1990 (Photographs 1-7). Those photogrephs show the six spans (arches), the piers and ebutments, the sidewalls (spandrel walls), the tie rod assemblies on the sidewalls, the railings, the 26 foot wide roadway with its two 13 foot driving lanes, and the 4.5 foot wide sidewalks. The present railing is like the replacement railing shown on the 1957 repair plans, and the tie rod assem-blies are detailed on the 1969 repair plens. Span lengths and the maximum length of the bridge ere the same es they were in 1969.

Sources of Information

Bibliography

Anonymous
1907 National Bridge Company, Indianapolis, Indiana, Reinforced Concrete Bridges, Luten Patents. Copy in the Indiana State Library, Indianapolis.

Anonymous
1930 Who's Who in America 16:1413, 1930-1931. The A.N. Marquis Company. Chicago.

Anonymous
1946 Luten Company President Dies. Indianapolis Star for July 4, page 14. Copy in the newspaper archives of the Indiana State Library, Indianapolis.

Anonymous
1950 Who Was Who in America 2:333. The A.N. Marquis Company. Chicago.

Juricic, James E.
1990 Concurrence letter of September 28 from Juricic (Manager, Environmental Assessment Section, Indiana Department of Transportation) to Arthur A. Fendrick (Division Administrator of the Federal Highway Administration in Indianapolis). Files of the Environmental Assessment Section of the Indiana Department of Transportation, Indianapolis.

Luten, Daniel B.
n.d. Reinforced Concrete Bridges of Luten Design. The Hollenbeck Press. Indianapolis. Copy in the Indiana State Library, Indianapolis.

O'Connor, Frank
1979 The National Bridge Company of Indianapolis from 1903-1925: A Case Study of American Industrialization. Paper prepared for a history seminar of Professor James Cooper at Depauw University. Greencastle, Indiana. Copy in the Indiana State Library, Indianapolis.

Ralston, Patrick R.
1990 Letter of February 8 from Ralston (Indiana State Historic Preservation Officer) to Arthur A. Fendrick (Division Administrator of the Federal Highway Administration in Indianapolis). Files of the Environmental Assessment Section of the Indiana Department of Transportation, Indianapolis.

Ridenour, James M.
1987 Letter of December 21 from Ridenour (Director of the Indiana Department of Natural Resources) to Linville R. Sadler (Chief of the Division of Location and Environment of the Indiana Department of Highways). Files of the Environmental Assessment Section of the Indiana Department of Transportation, Indianapolis.

Personal Communication

Bartlett, Mahlon
1992 Information from the collection of state highway maps in the Highway Inventory and Systems Section of the Indiana Department of Transportation, Indianapolis.

Newspaper Accounts of the 1913 Flood and the Cicott Street Bridge

Copies of the following Logansport, Indiana, newspapers for 1913 are in the newspaper archives of the Indiana State Library, Indianapolis.

Logansport Journal-Tribune (LJT)
Logansport Pharos (LP)
Logansport Pharos-Reporter (LPR)

Present-Day Cicott Street Bridge

Photographs 1-7*	Photographs of the Cicott Street Bridge taken in November 1990.

Historic View of the Cicott Street Bridge

Photograph 8	Photograph of a postcard postmarked 1949 of the Cicott Street Bridge. Postcard in the Cass County photograph file at the Indiana State Library, Indianapolis.

Engineering Drawings

Photographs 9-12	Photographs of sheets 1, 5, 6, and 12 of the 1957 repair plans of the Cicott Street Bridge. Plans in the files of the Division of Design of the Indiana Department of Transportation, Indianapolis.
Photographs 13-16	Photographs of sheets 1-4 of the 1969 repair plans of the Cicott Street Bridge. Plans in the files of the Division of Design of the Indiana Department of Transportation, Indianapolis.

Supplements (attached as pages 13-25 of this report)

Title page and pages 82-93 of "National Bridge Company, Indianapolis, Indiana, Reinforced Concrete Bridges, Luten Patents." Published 1907. No author or publisher given. Copy in the Indiana State Library, Indianapolis.

*All photographs illustrating this report are in envelopes that are accompanied by an "Index to Photographs."

Cicott Street Bridge
HAER No. IN-69 (Page 11)

Figure 1

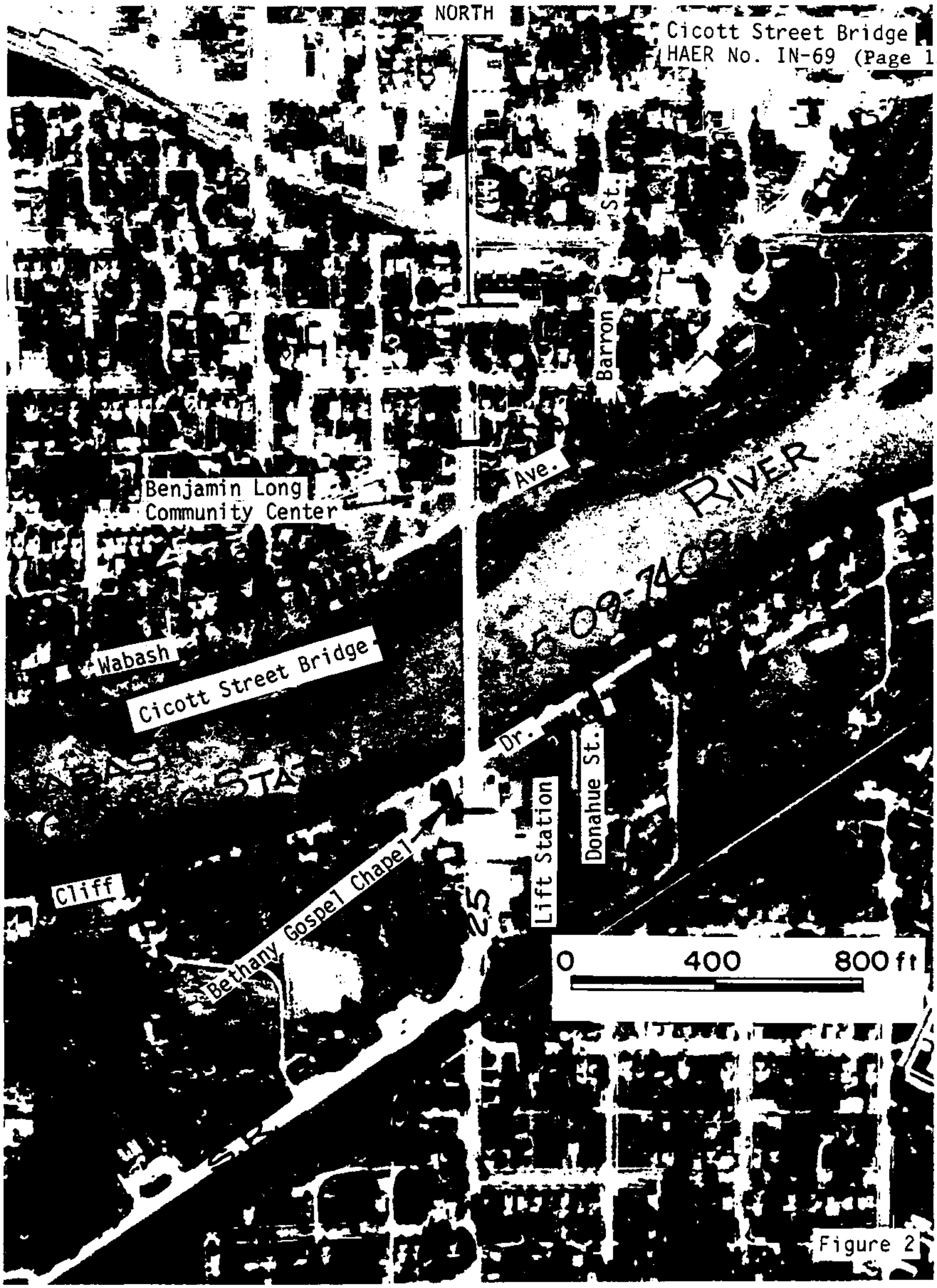

NORTH
Barron St.
Ave.
RIVER
Benjamin Long Community Center
Wabash
Cicott Street Bridge
Dr.
Donahue St.
Lift Station
Cliff
Bethany Gospel Chapel
25
0 400 800 ft

Figure 2

NATIONAL BRIDGE COMPANY

INDIANAPOLIS

INDIANA

REINFORCED CONCRETE BRIDGES
LUTEN PATENTS

REPRESENTATIVES:

National Bridge Co.
514 O. T. Johnson Bldg.,
Los Angeles, Cal.

National Concrete Co.,
805 Traction Terminal Bldg.,
Indianapolis, Ind.

Topeka Bridge & Iron Co.,
Topeka, Kan.

Illinois Bridge Co.,
Monadnock Block,
Chicago, Ill.

Berlin Construction Co.,
Berlin, Conn.

N. M. Stark & Co.,
DesMoines, Ia.

Ferro-Concrete Co.,
Philadelphia, Pa.

1907

PATENTS AND ROYALTIES

The Luten arch is the result of seven years of experience in the design *and erection* of reinforced concrete arches. Upwards of forty improvements have been made for the purpose of decreasing its cost and increasing its strength, until we now have a stronger arch by fifty per cent than any other type that can be erected at the same cost. We have been to great expense in developing this structure and in advertising its advantages. We have consequently applied for patents on every improvement, and we now own more cost-saving patents on reinforced concrete arches than all other builders.

Preliminary Plans:—We will supply preliminary plans without charge.

Royalty:—The steel reinforcement in our bridges, to be effective, must be of good quality and workmanship and properly placed in the arch. We will furnish the steel as specified, with the working drawings and engineering advice and the license to erect any particular bridge for an agreed amount dependent upon the design, and which will be named in the specifications, thus throwing our plans open to general competition. Or, we will supply the working drawings and the license for a royalty of ten per cent of the contract.

Skilled Foremen:—We have in our employ upwards of thirty foremen experienced in the erection of this type of bridge, and capable of handling spans of 150 ft. or under. We will loan skilled foremen to contractors erecting our bridges.

Every design filed by the National Bridge Company involves from ten to twenty cost-saving devices under our patents. Compared with the royalties charged by other patentees for the use of a single patent, our terms are the lowest.

It has been decided again and again by the highest courts that when bidders are given the opportunity to buy the right to build a patented structure, the competition is genuine, and a public letting of such a structure is legal.

When an individual wishes to make a purchase he secures the best at the lowest price regardless of whether or not the device is patented; why, then, should the public be denied the same privilege?

A farmer who would cut his grass with a scythe because the mowing machine is patented, would have to eat grass to live, in this progressive age.

METHOD OF DESIGN

Almost every writer on the theory of the elastic arch, now commonly accepted as the most satisfactory method of analyzing steel arches, has excused the laborious process when applied to masonry arches by making the statement that although this cut and try process is exceedingly tedious, especially when the section of arch first assumed is found to be erroneous, nevertheless a designer skilled in this analysis can nearly always select a satisfactory section at the first trial and thus avoid repeating the tiresome process. If it be true that a skilled designer can thus by inspection select an appropriate section, there certainly ought to be derived an empirical method of design that would enable the skilled designer to transmit his skill in inspection to his less fortunate unskilled associates.

It is, however, not surprising that writers like Eddy, Greene, Howe and Cain, who have confined themselves to the development of the elastic theory of arches, and who have had little or no actual experience with the erection of reinforced concrete arches, should have failed to point the way to snch an empirical method. It remains for practical men who are erecting such arches under all conditions of loading and location, to evolve an empirical method that shall eliminate the numerous doubtful. assumptions essential to a solution by the elastic theory, at the same time that it reduces the process of design to a simplified working basis.

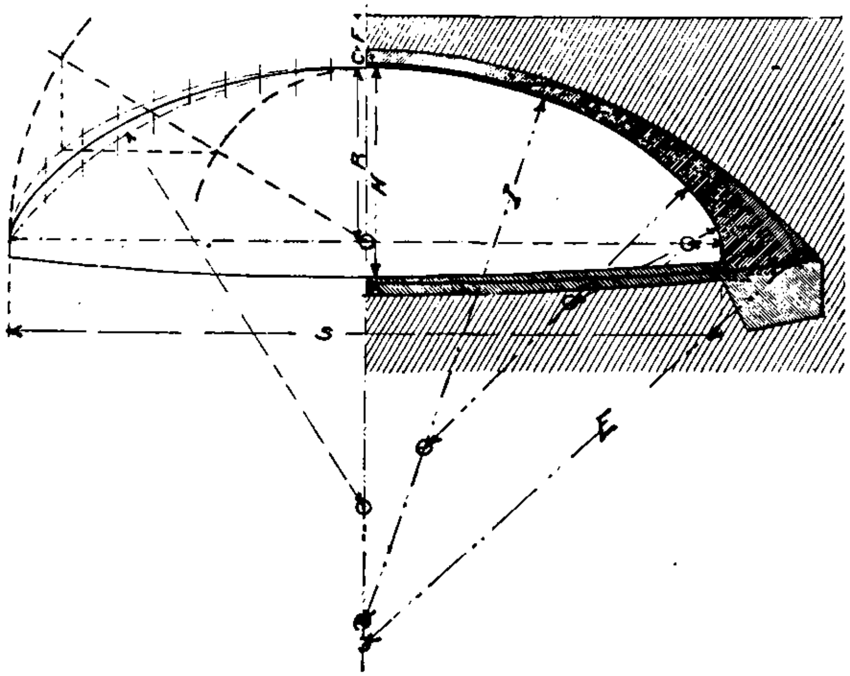
One of the many remarkable properties of reinforced concrete is that when the embedded steel is stressed upwards of 10,000 pounds per square inch, slight hair cracks will appear in the concrete. Thus it is possible to know something of the condition of stress in the structure without testing to destruction.

The method of design now used by the National Bridge Company on all arch designs was developed from four years' experience in designing arches by the elastic theory and by the two-nosed catenary method, during which time over three hundred arches were erected and studied. The method has since been applied to upwards of four hundred arches, varying in spans from three feet to 105 feet, with invariable success.

The method applies to earth-covered arches only, but for this type of arch it offers a solution that is ideal. The method is based on the linear arch for the earth loading, and should not be applied to parabolic arches or circles unless full-centered.

In fifteen minutes a skilled draftsman can determine the complete section, including the reinforcement required, for a reinforced arch for any span and loading. And the resulting structure is a safer and more logical type of arch than can be designed by the assumption of a hap-hazard section, as by the elastic theory, and then testing that section to determine its stability.

The empirical formulas are based on allowable safe stresses in the concrete of 350 pounds per square inch in compression, fifty pounds per squsre inch in shear and no tension, and in the steel of 15,000 ponnds per square inch in tension.



CONCISE STATEMENT OF METHOD OF DESIGN
(WITH ABUTMENT TIES)

1. Determine the inner curve of the arch as follows: Draw an ellipse of the required span and rise; pass a segment of a circle through crown and springings of ellipse; bisect the vertical distances between the ellipse and the circle; approximate the resulting curve by arcs of circles, adjusting the curve at the springings to become tangent to the verticals.

2. Lay off the crown thickness=

$$\frac{3\text{ Span}^2\ (\text{Rise}+3\text{ Fill})}{4{,}000\text{ Rise}-\text{Span}^2}+\frac{\text{Uni. Load x Span}^2}{30{,}000\text{ Rise}}+\frac{\text{Con. Load }(\text{Span}+5\text{ Rise})}{150\text{ Rise}}+4$$

3. Draw the outer curve as a circle of radius=

$$\text{Radius Inner Curve at Crown}+\frac{\text{Crown Thickness}}{6}$$

Produce this circle to the level of the springing line and then continue its tangent to meet the abutment ties produced.

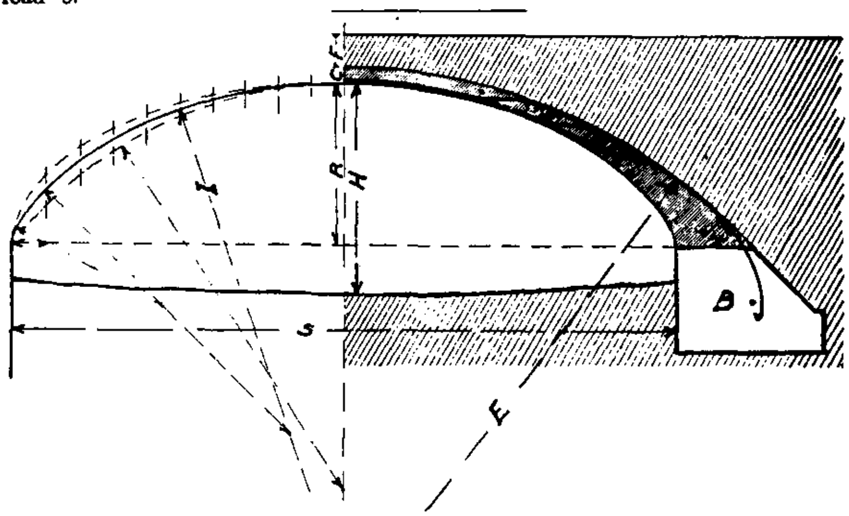
4. Diameter Abutment Ties $=\frac{1}{2}\sqrt{\text{Spacing }(2\text{ Crown}-\text{Height})}$

5. Diameter Arch Rods $=\sqrt{\text{Spacing}\frac{(\text{Span x Con. Load})}{250\text{ Crown}}}$

NOTE:—An ellipse is easily drawn as shown on the left of the above figure, by striking two concentric circles with the middle of the span as center and passing respectively through the crown and through the springing, then drawing any radius intersecting the two circles and projecting the points of intersection parallel to the span and to the rise until they intersect each other in a point of the ellipse.

NOTE:—Crown thickness and diameter of ties and rods in inches; concentrated loading consists of maximum live loading on single track over half-span in tons; uniform live load in pounds per sq. ft; all other dimensions in feet. Spacing is distance between rods or ties in feet. In the above figure, Height is indicated by H, Radius of Inner Curve by I, Radius of Outer Curve by E, Rise by R, Span by S, and Fill by F.

NOTE:—If uniform live load and concentrated live load are not applied simultaneously on arch, then the larger only of the terms involving these quantities should be used in the crown formula. For railroad bridges, uniform live load=0.



CONCISE STATEMENT OF METHOD OF DESIGN

(WITHOUT ABUTMENT TIES)

1. Determine the inner curve of the arch as follows; draw an ellipse of the required span and rise; pass a segment of a circle through crown and springings of ellipse; bisect the vertical distances between the ellipse and the circle; approximate the resulting curve by arcs of circles, adjusting the curve at the springings to become tangent to the verticals.

2 Lay off the Crown Thickness=

$$\frac{3\ \text{Span}^2\ (\text{Rise}+3\ \text{Fill})}{4{,}000\ \text{Rise}-\text{Span}^2}+\frac{\text{Uni. Load x Span}^2}{30{,}000\ \text{Rise}}+\frac{\text{Con. Load}\ (\text{Span}+5\ \text{Rise})}{150\ \text{Rise}}+4$$

3. Draw the outer curve of the arch as a circle of Radius=

$$\text{Radius Inner Curve at Crown}+\frac{\text{Crown Thickness}}{6}$$

Continue this circle to the level of the springings and then continue its tangent.

4. Lay out the abutment with an area below the springing and adjacent the back tangent$=\frac{4\ (2\ \text{Crown}-\text{Height})}{\text{Coefficient Friction.}}$

5. Diameter Arch Rods$=\sqrt{\text{Spacing}\frac{(\text{Span x Con. Load})}{250\ \text{Crown}}}$

NOTE:—Crown thickness and diameter of rods in inches; concentrated load consists of maximum live loading on single track over half-span in tons; uniform live load in lbs. per sq. ft; abutment area in square feet; all other dimensions in feet. In above Figure, Height is indicated by H, Span by S, Rise by R, Fill by F, Radius Inner Curve by I, Radius Outer Curve by E, and Area of Abutment by B. Coefficient of friction of concrete on earth may be taken at unity for hard clay.

NOTE:—If uniform live load and concentrated live load are not applied on bridge simultaneously, then the larger only of the terms involving these quantities should be used in the crown formula. For railroad bridges, uniform live load=0.

DESCRIPTIVE ARTICLES IN TECHNICAL JOURNALS.

"Double-Drum Concrete Arches."
—*Engineering News,* May 3, 1906.

"Horse-Shoe Concrete Arches,"
—*Railroad Gazette,* April 20, 1906.

"Curves for Reinforced Arches,"
—*Engineering Record,* April 14, 1906.

"Empirical Formulas for Reinforced Arches,"
—*Engineering News,* June 28, 1906.

"The Beam Culvert, an Inefficient Structure,"
—*Engineering News,* May 24, 1906.

"Hard Steel and Soft, for Reinforcement,"
—*Engineering News,* July 20, 1906.

"Reinforced Concrete Bridges,"
—*Street Railway Journal,* August 18, 1906.

"A 40 Ft. Reinforced Girder Bridge,"
—*Engineering News,* May 10, 1906.

"Twentieth Century Bridges,"
—*Good Roads Magazine,* November, 1906.

"East Washington Street Bridge, Indianapolis,"
—*Municipal Engineering,* July, 1906.

"Wayne Street Bridge, Peru, Indiana,"
—*Engineering News,* March 29, 1906.

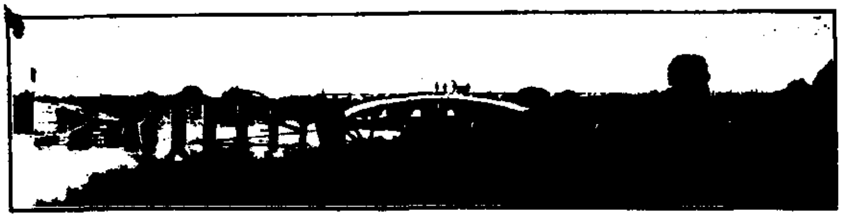
"Reinforced Concrete Bridge at Yorktown, Indiana,"
—*Engineering News,* May 11, 1905.

"Concrete Bridges,"
—*Street Railway Review,* April 15, 1906.

"Design of a Concrete-Steel Arch-Bridge."
—*Engineering News,* May 8, 1902.

"Design of a Concrete Railroad Bridge,"
—*Railroad Gazette,* May 11, 1900.

"Tests of Arch Models to Determine the Value of Tie-Rods,"
—*Engineering News,* February 15, 1900.



DETAILS OF ERECTION

Skilled Foremen:—The Luten type of arch, requiring but a single series of reinforcing members, is the simplest and easiest type of reinforced arch to erect that has yet been devised. But even this type demands foremen possessing a high degree of skill in order to accomplish proper construction with economy of cost and handsomely finished appearance. There is probably no material that is more susceptible than concrete to the hand of the master workman, nor any that is more easily disfigured and disfaced by the unskilled amateur. To become a skilled foreman in this line of work, it is not alone sufficient that a man should learn by costly experience at the expense of bridge after bridge, but each should learn the profession by apprenticeship under a skilled foreman of wide experience. We have now in our employ upwards of thirty skilled foremen and fifty assistants.

Foundations and Piling:—The foundations for this type of structure are not unlike those of any other arch. If the flood-proofing pavement is not employed, then care must be taken to place the footings on solid bearings of clay or hardpan. In sand or gravel foundations subject to scour, piling may be required to prevent undermining. But if the flood-proofing pavement is employed, the footings may be placed on sand or gravel without piling. We have erected bridges provided with this pavement with their foundations resting on quicksand, which when thus confined makes a satisfactory foundation. Of the hundreds of bridges which we have erected with the flood-proofing pavement, only two have piled foundations.

Laying Flood-Proofing Pavement:—The process of laying a six-inch concrete pavement across the bed of a stream and embedding the steel ties from abutment to abutment, under two or three feet of water, seems to most contractors a difficult operation. Yet when it is understood that steel rods may penetrate an earthen cofferdam without causing it to leak, the process becomes simplicity itself. Thus as shown in Fig. 8, the stream may be diverted to one-half span while the other half is being paved. The concrete pavement is shown in place in the foreground two or three feet below the level of the stream surface on the farther side of the earthen coffer dam. A new cofferdam is in process of construction at the right foreground, in order that the stream may be diverted over the finished pavement while placing the uncompleted portion. A small stream may be dammed and sluiced across, or diverted back of abutment in some cases. These pavements have been successfully laid in six feet of water across an eighty-foot span. It is doubtful, however, whether such a pavement has any economic value in reducing the first cost of the structure when the depth of water exceeds four feet. The actual saving in concrete for any particular arch may be readily determined by comparison of the two methods of design on pages 84 and 85.

Erection of Centers:—When the flood-proofing pavement is employed, the design of the centers is a mere matter of column and beam formulas. In other cases the foreman must exercise his judgment in securing a satisfactory support

FIG. 8. LAYING FLOOD-PROOFING PAVEMENT IN EAST WASHINGTON ST. BRIDGE

(See pages 22 and 23.)

by the use of piling, or of concrete sills, or trusses. In any case, since nailed joints cannot be safely estimated, it should be the duty of the foreman to constantly inspect the centers while the concrete is being placed to detect any signs of weakening. It is only by impressing upon the foreman that he is to be held personally responsible for the stability of the centers, that any economy of design can be attained in the drafting room. Note for example the light centering employed in three spans of the Plainfield Bridge, page 45, and in Wayne Street Bridge, page 81. The centering of Fig. 9 consists of flexible uprights braced at frequent intervals by sway bracing. Where floods are to be feared, the uprights may be flexible in the direction of the stream and braced in that direction only.

In spans of fifty feet or more, centers should be struck before completion of copings or railings in order that the settlement of the arch may be effected without rupture of the stiff monolithic spandrels or railings. The arch should be loaded before the centers are struck.

The length of time that centers should remain in the arch depends on the span and on temperature conditions. In summer temperature of 70 or 80 degrees, the centers may be struck after as many days as one-fifth the span.

Placing Steel:—For convenience in handling and placing as well as for economy of material, it is desirable that the steel should be welded into lengths complete from end to end of span. These welds are readily concentrated in the regions of minimum bending moment where the reinforcement crosses the ring, and they will then be subjected to very slight stress. Or the rods may be lapped and wired. When abutment ties are used, the arch reinforcement may be connected to them by open hooks sufficient only to hold them in place. Otherwise anchor rods may be embedded in the footings to facilitate fastening of the arch rods.

In Fig. 10 is shown the single series of longitudinal rods in place consisting of ¾ inch rods spaced 18 inches, and the transverse rods, ¾ inch spaced ten feet. Transverse straps of ⅛x1 inch steel are also shown passing under the longitudinal rods and curving upwards to be embedded in the body of the arch ring to prevent the longitudinal rods from tending to straighten under tension, shearing through the soffit of the arch. These straps are also shown in the sections of Fig. 3.

In Fig. 11 is shown the arrangement of the longitudinal reinforcing members at the points of crossing the arch ring, the alternate members of the single series crossing at different points so as to reinforce both inner and outer surfaces through the limited region of shear. Mild steel rods are readily bent cold to cross the arch ring, with the aid of a "goose-neck" procurable from any blacksmith. The reinforcing rods are here shown wired to a 2x4 cross timber which is all the bracing needed to hold them in place for the half of the span. Along the crown the rods are nailed to the drum temporarily and then blocked up to receive the concrete.

Method of Concreting:—The footings are of course concreted first, then the centers erected, on the pavement where one is used, after which the arch ring should be concreted in concentric rings continuous from abutment to abutment. Where there is probability of unequal settlement of the centers these concentric rings may be made as narrow as three or four feet say in order to avoid loading the haunches too heavily before loading the crown. Or the ring may in such cases be divided into sections transverse to the roadway and alternate sections concreted so as to load the centers gradually and uniformly. The former method is, however, to be preferred both for economy in erection and for strength.

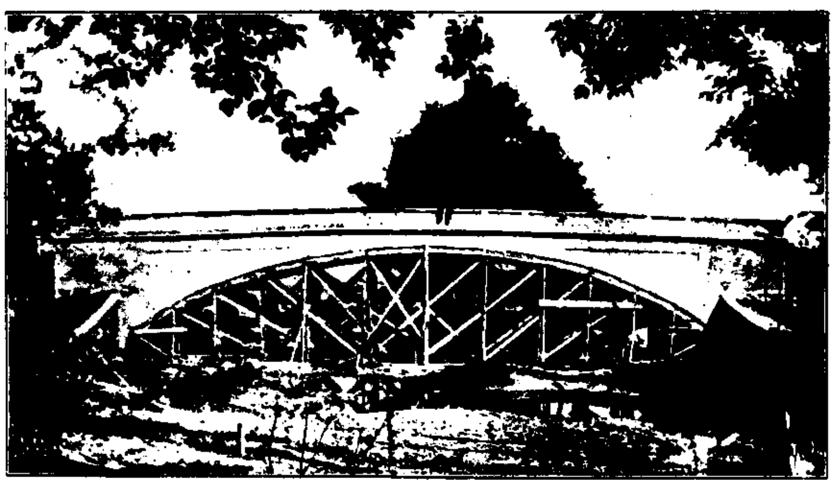


FIG. 9. COLLAPSIBLE CENTERING IN CLIFTY CREEK BRIDGE

(See pages 38 and 39.)

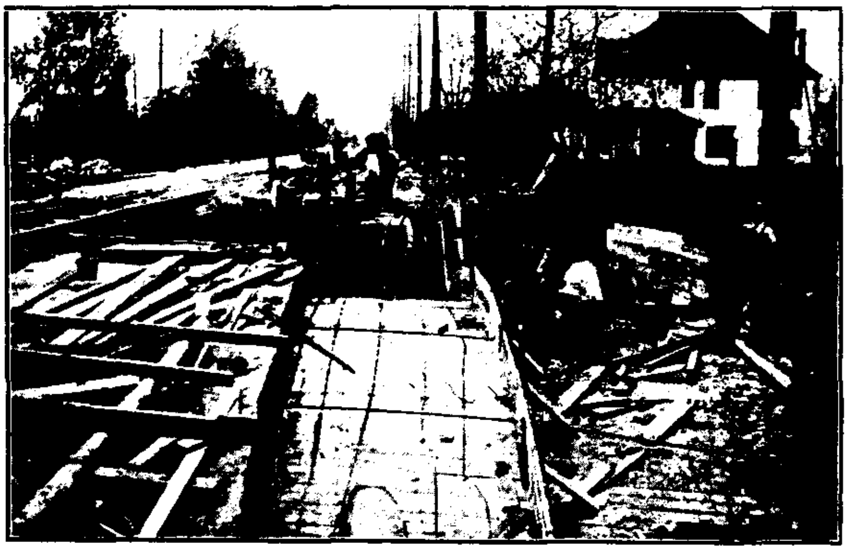


FIG. 10. EAST WASHINGTON STREET BRIDGE, INDIANAPOLIS
Under construction, showing partially completed ring, and steel and bulkhead in place for an additional section.

In concreting continuous spans joints may be made in the arch rings at springing and at alternate skewbacks. Spandrel walls should be concreted continuously from end to end of span and monolithically with the end section of the ring, so that no joint of division will appear on the face of the spandrel, except the vertical expansion joints above the springings. The spandrel extensions and the posts over piers are subsequently concreted, the line of junction providing an expansion joint. A grooved form should be inserted in the end of one of the sections adjacent the expansion joint (and may be left embedded in the concrete),

SAN DIMAS, CALIFORNIA

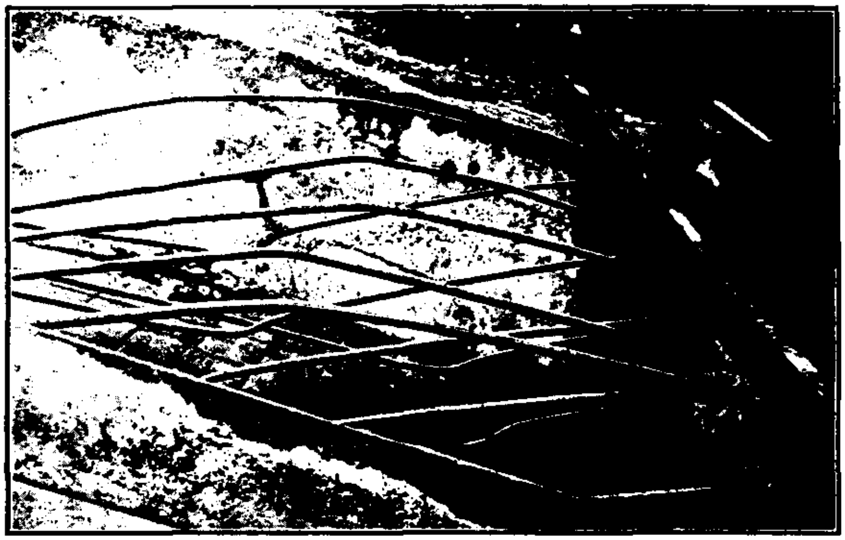


FIG. 11. SHOWING STAGGERING OF ALTERNATE REINFORCING MEMBERS THROUGH THE SHEARING REGIONS

to drain the seepage through the arch ring and prevent it from discoloring the spandrel face.

Loading:—The earth filling should be added before striking centers if feasible. Otherwise care should be taken in applying a heavy fill, to load it with some uniformity, as the stresses induced by an eccentric application of heavy earth filling may be enormously in excess of any reasonable loading.

Finish:—A concrete bridge should never be white-washed with a cement wash. Time will accomplish all that is desirable in whitening a properly finished concrete bridge.

OVERHEAD CROSSING, LIMA & TOLEDO TRACTION RY., LIMA, OHIO

ADVANTAGES OF REINFORCED CONCRETE BRIDGES

A properly constructed concrete bridge is absolutely indestructible.

A concrete bridge is the only bridge that grows stronger with age.

As time passes traffic on our highways grows heavier; steel and wooden bridges grow weaker; concrete bridges grow stronger. To build a concrete bridge, then, is just plain common-sense.

Portland Cement is the most perfect coating known for the protection of steel.

A concrete bridge provides a continuous gravel roadway. Wooden floors for bridges are an expensive nuisance. Concrete bridges require no floor renewals.

CONCRETE BRIDGE, INDIANAPOLIS, IN 1905 FLOOD

Concrete bridges are rust-proof, frost-proof, flood-proof and fire-proof.

Concrete bridges require neither painting nor repairs.

Concrete bridges are permanent improvements.

A concrete bridge can be widened at any time without re-building.

To make a bridge flood-proof, pave the bed of the stream to prevent scour, and then build the bridge in a solid monolithic mass so that it will stay.

A concrete bridge once built, is built for all time.

Concrete bridges are built with labor hired from the immediate vicinity of the bridge; with gravel or stone purchased in the immediate locality, and with cement secured, from local agents. The greater part of the expense for such a bridge is thus returned to the county.

The money that tax-payers expend for a concrete bridge is returned to the tax-payers for labor and materials.

The beauty of horse-shoe concrete arches lies in their common-sense.

Concrete bridges are the handsomest for park bridges, the most durable for highway bridges, the most serviceable for railway bridges.

Bridges built of concrete will endure as monuments for all time.